A COMPUTER PROGRAM TO ANALYZE BENDING OF BENT CAPS

By

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SUMMARY REPORT 56-2 (S)

SUMMARY OF
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Foreword

Research Report No. 56–2 presents a particular application of the beam-column method for the analysis and design of highway bridge bent caps. It is the second in a series of reports that describe the work for Research Project 3–5–63–56, entitled "Development of Methods for Computer Simulation of Beam-Columns and Grid-Beam and Slab Systems."

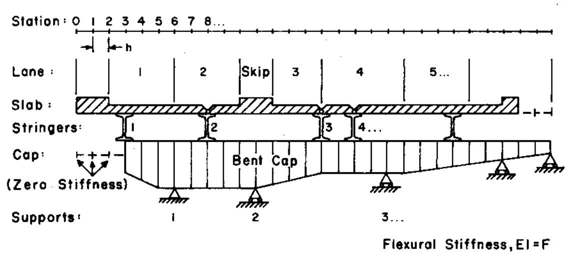

Fig 1. Elements of bent-cap problem.

Introduction

In the design of highway bridge structures, prescribed configurations of live load are placed on the structure in such locations that maximum stresses are reached at each of many critical points. The analysis of complete structures or structural systems under all possible loading conditions is at present a complex and time-consuming problem. In current design practice it is therefore necessary (1) to make severe simplifications in the structure and in the transference of loads, so that a piecemeal analysis may be performed, and (2) to reduce the complexity of loadings by the application of considerable individual judgment. Even with these shortcuts, a great amount of effort is required by manual methods.

The purpose of the report is to describe the CAP program, which uses a simplified adaptation of the BMCOL method (Ref 1) to analyze the bending of a highway bridge bent cap under various controlled loading situations. Sufficient detail is included so that the uninitiated user may understand the workings of the program and may apply it to problems of design.

The Method of Analysis

The method of analysis used to solve bridge bent caps is the same as that presented in Ref 1. The finite-element representation of a generalized bent cap in which loads are transmitted through a slab and stringer system is shown in Fig 1. The structure is pictured somewhat distorted to show generality. The supports are represented by knife-edges. Caps may be skewed with respect to the roadway centerline. The stringers rest on the cap and the roadway slab on the stringers. The slab may have curbs and a median and may be divided into lanes, usually according to AASHO design specifications (Ref 2). Simple-span distribution of slab loads is accomplished by the assumption of a hinge in the slab at each interior stringer.

The loads that are distributed to the cap are of two types: dead loads developed directly from the dead weight of the stringers and the cap itself; and reactions at the stringer locations from simple-span distribution of slab loads, which consist of dead weight of the slab, curbs, sidewalks, and medians plus live loads that can be moved to represent traffic loadings.

The live loads that are moved may be of any configuration. They are moved in combination with any specified number of lanes (load configuration patterns) at all points across the slab to generate the maximum design values at each location. In the usual application of the program, AASHO-type multiple-lane loads will be arranged to produce maximum and minimum values of each design-control variable at each design-control point.

The effects of various dead and live loadings are not obtained separately and then superposed. Instead, each individual BMCOL-type solution constitutes a separate computer simulation of a complete structural system, including all dead and live loads that may be acting at the time.

After a solution is performed with each specific pattern of loads, the resulting design variables (bending moment, shear, and support reactions) are compared at every station with the previous maximum and minimum values at that station. Whenever a new value is found that is more extreme than that retained from previous solutions, the new value replaces the old one. The resulting tabulations constitute envelopes of maximum positive and maximum negative effects at each station that have been progressively developed by the complete history of the loading.

The Computer Program

The specific version of the CAP program that is described in this report is designated as CAP 14. The program developed in Ref 1 is used as the basis for the CAP 14 program. It is permissible to use up to three hundred increments, ten lanes, twenty supports, thirty stringers, thirty design points for moment, and thirty design points for shear. Each support is automatically a design point for reaction. There is a maximum number of five multiple-lane load-reduction factors and the solution is limited to five or fewer simultaneous lane loads.

There are several options which the user may apply at his discretion and for his particular needs. Among them are retaining the envelopes of maximums from problem to problem in order to study cumulative effects of various loading situations, holding the input of data from problem to problem, and plotting the envelopes of maximum and minimum moment and shear.

CAP 14 does not output any of the deflections computed for the cap. Moment and shear diagrams from any particular loading are not directly available, but can be obtained in the form of identical maximum and minimum envelopes if a problem is arranged so that there is only one loading pattern considered. Where such results are desired, the BMCOL program (Ref 1) normally should be used.

A Guide for Data Input is included which the designer may refer to for application and use of the program.

A basic example problem with variations is shown in the report as an aid to understanding the use of the input data forms and to demonstrate the application of the program for design use. One variation of the example problem is shown in Fig 2. The movable-lane load is positioned at all points within the specified lane boundaries. Up to four movable-lane loads are placed by the program at all possible positions and combinations of positions within each lane. For each position and number of lanes loaded, a distribution of the loads from the slab is made to the cap, and a BMCOL solution is solved. The values of shear and moment that are computed for each point in the cap are compared to prior values for other loading patterns and positions. The maximums of these design variables are retained and tabulated in envelopes of maximums. A provision is available in the program to plot these envelopes. The envelopes of maximum bending moment and maximum shear are shown for this problem in Fig 2b and Fig 2c. In addition,

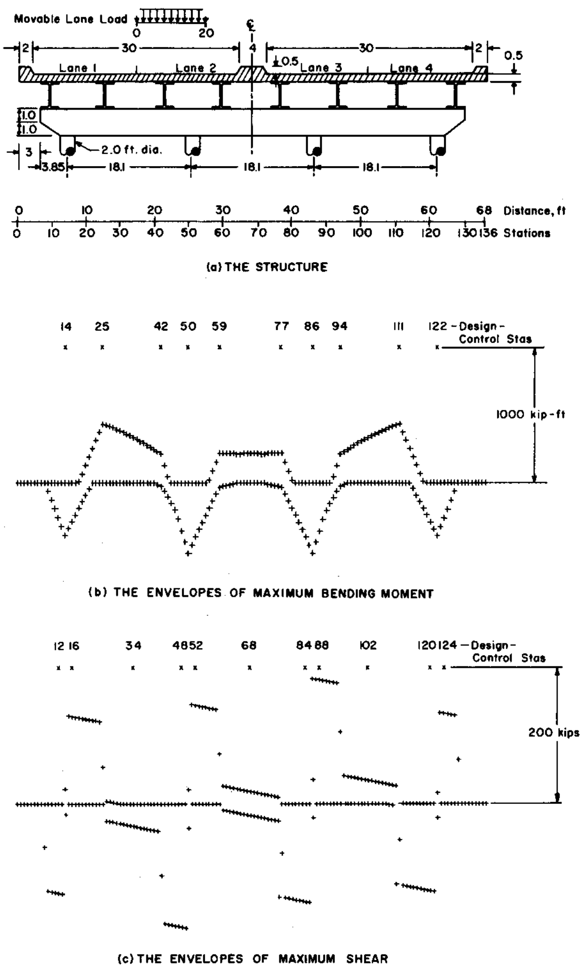

Fig 2. A typical bent-cap problem.

the maximum values of all the support reactions are computed and tabulated. These values can be used directly by the highway bridge designer for the bent-cap design.

Conclusions

Research Report No. 56–2 presents an application of the BMCOL method (Ref 1) in which the basic program is adapted to current design practices. CAP 14 should be used to study ways of improving or simplifying the more or less arbitrary loading rules that are currently used. Specifically, it is felt that through the use of CAP 14, a fixed pattern of movable loads may be evolved that will give equally satisfactory results when compared to those based on the intricacies of the AASHO rules. A fixed pattern of movable loads would greatly reduce the amount of logic and computation needed and in turn might considerably reduce the overall cost of analysis. This will be increasingly important as larger and larger aggregations of structural elements are considered in more sophisticated computer programs of the future.

References

1. Matlock, Hudson and Haliburton, T. A., "A Finite-Element Method of Solution for Linearly Elastic Beam-Columns," Research Report No. 56-1, Center for Highway Research, The University of Texas, Austin, September 1, 1966.

2. *Standard Specifications for Highway Bridges,* Eighth Edition, American Association of State Highway Officials, Washington, D.C., 1961.